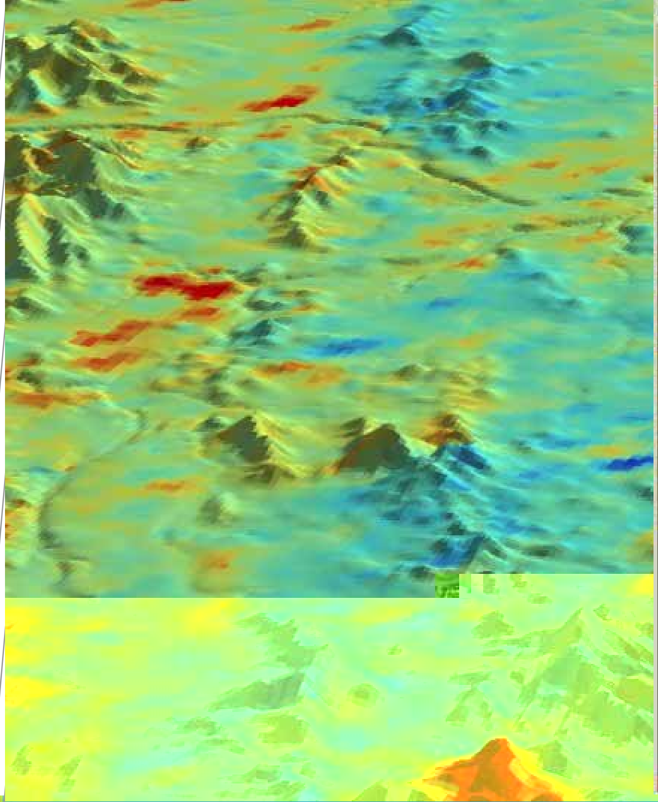
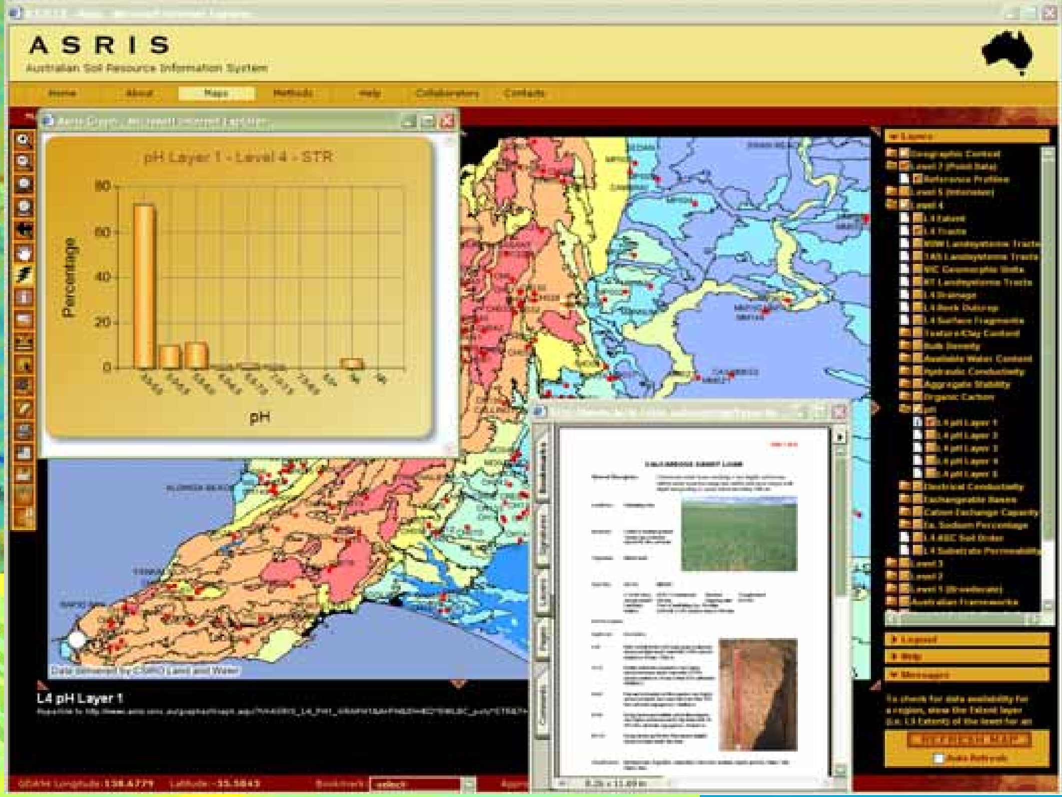




www.csiro.au

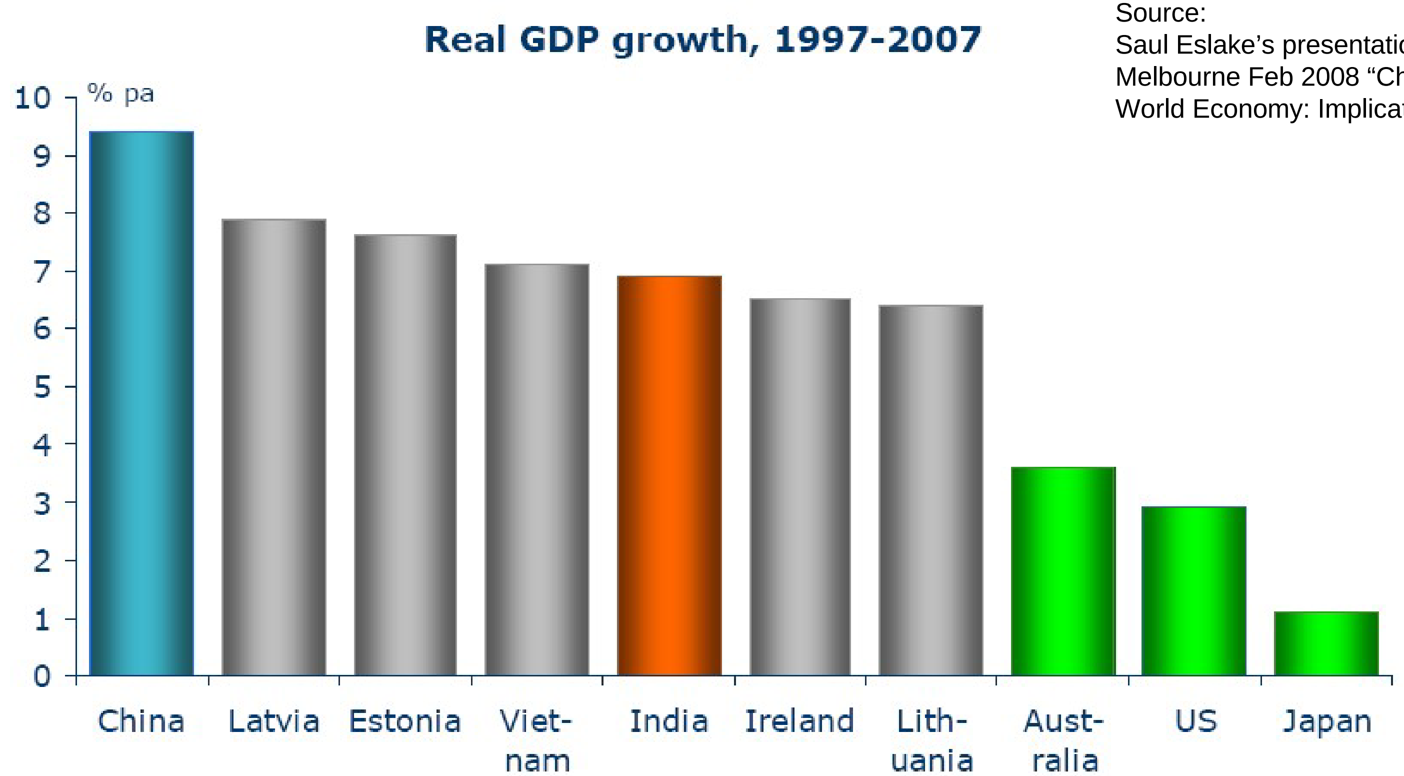
Challenges and priorities for soil survey – the Global Soil Map

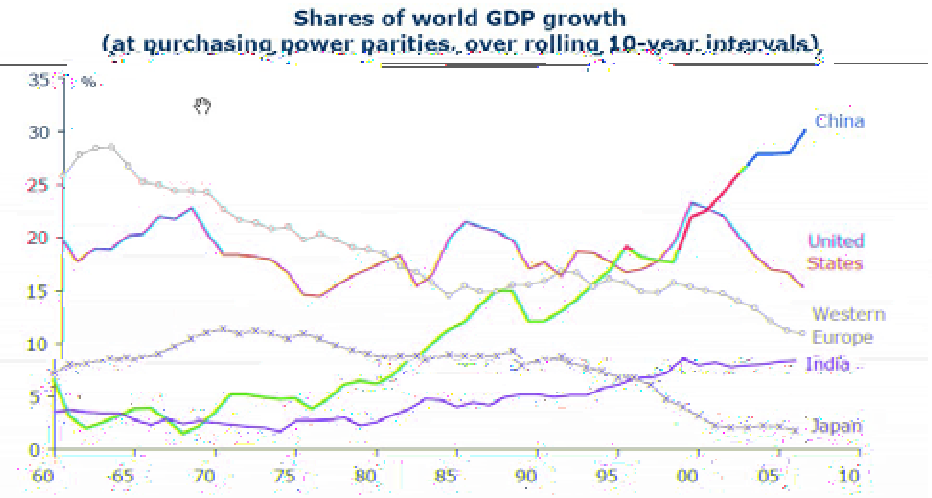
Mike Grundy, CSIRO, Australia

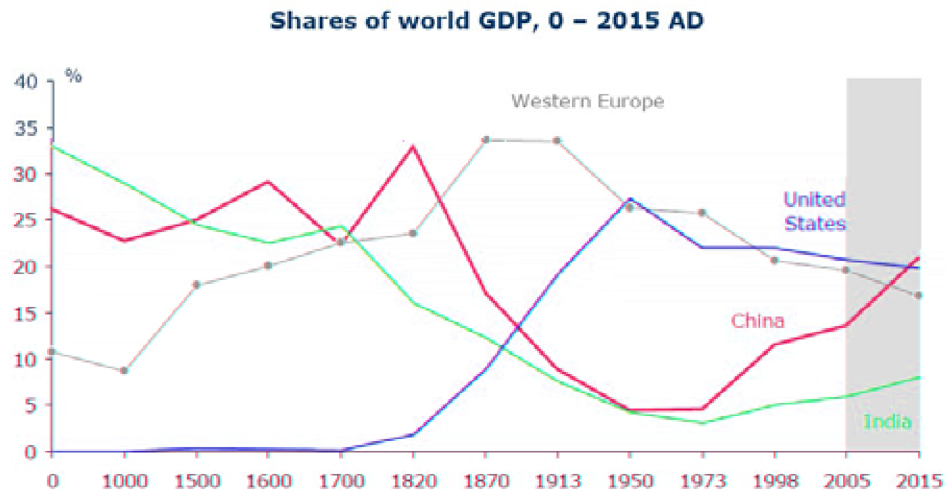
CSIRO

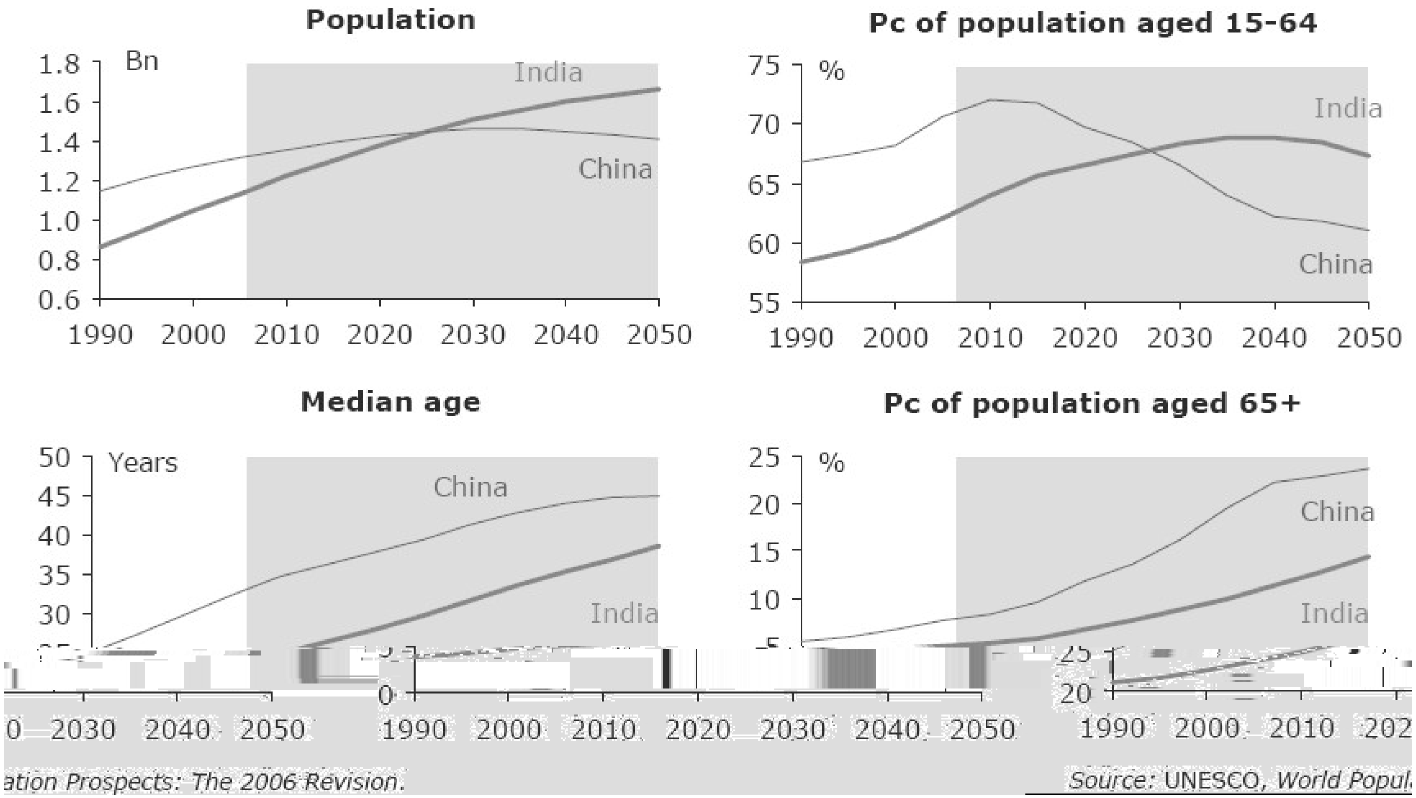
- Setting a world scene
- A soils response – a global soil information system
- What it needs to look like
- Getting there
- Briefly – an Australian picture

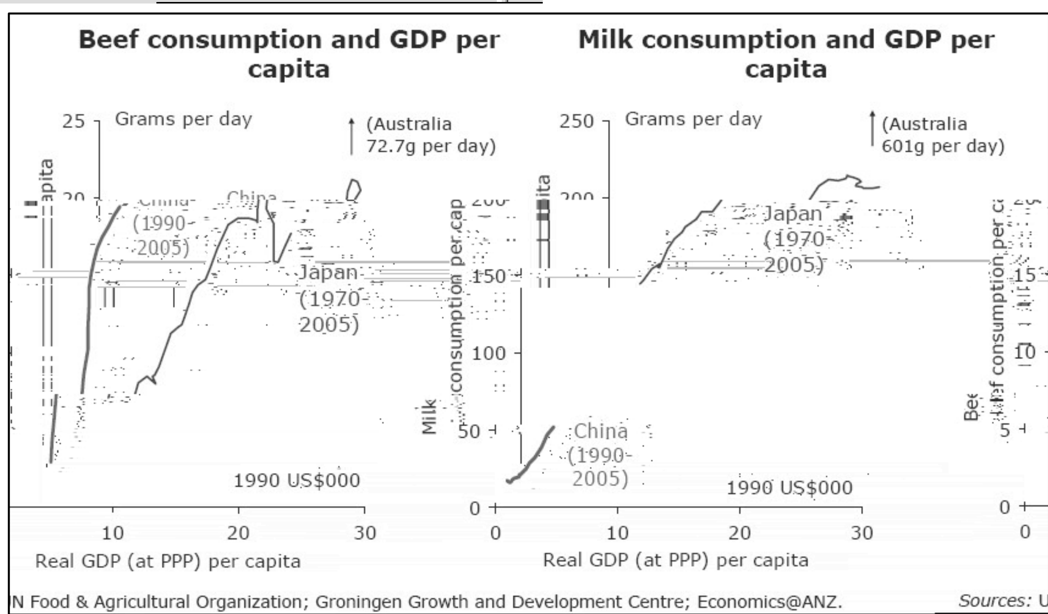
Source:
Saul Eslake’s presentation to CFO Forum Melbourne Feb 2008 “China & India in the World Economy: Implications for Australia”











Source:
Saul Eslake's presentation to CFO Forum Melbourne Feb 2008 "China & India in the World Economy: Implications for Australia"

Rice-Wheat Consortium for Indo-Gangetic Plains http://www.rwc.cgiar.org/rwc/table.htm

Supply and Demand Projections for Rice and Wheat, South Asia

Country	Population 1990[a]	1990-2020 Growth Rate [b]	2020 Rice Production	2020 Rice Demand	2020 Rice Balance	2020 Wheat Production	2020 Wheat Demand	2020 Wheat Balance
Bangladesh	106.70	1.8	38,071.00	38,024.00	(132.00)	1,580.00	6,031.00	(4,450.00)
India	849.50	1.7	145,777.00	144,792.00	985.00	96,384.00	95,617.00	766.00
Nepal	18.90	1.8	3,814.00	2,407.00	860.00	1,401.00	1,357.00	44.00
Pakistan	112.40	2.8	6,207.00	5,309.00	898.00	27,463.00	42,914.00	(15,451.00)
South Asia	**1,147.70**	**1.8**	**197,617.00**	**197,588.00**	$\boxed{\textbf{29.00}}$	**126,817.00**	**148,121.00**	$\boxed{\textbf{(21,303.00)}}$

[a] In millions; [b] in Percentage

Source: Hobbs and Morris, 1996

Close

A world of new challenges and constraints

- Developed world:
  - 765m ha cultivable land (268m with significant limitations) – 595m used
- Developing world:
  - 1.8b ha cultivable land (360m with significant limitations) – 900m used
- Where is the unused land?
  - sub-Saharan Africa; South America
  - 770m ha in forests
- and, increasingly, cultivable land used for biofuels

"Intensification of agriculture will be the most likely means to meet food needs for a world population of some nine billion people in 2050"

From *Global Agro-ecological Assessment for Agriculture in the 21st Century – Fischer et al. 2001*

Indo-gangetic plain

- Soil fertility declines well recorded:
  - declining trend in productivity even with the application of N, P, and K fertilizers, and the use of modern intensive farming
  - micro-nutrient deficiencies started appearing, zinc deficiency widespread
  - Soil salinity and water logging already affects large parts of the IGP in India and Pakistan and to some extent in Bangladesh
  - Climate change: Changes in temperature and in precipitation patterns and amount will influence soil water content, run-off and erosion, workability, salinisation, biodiversity, and organic carbon and nitrogen content.

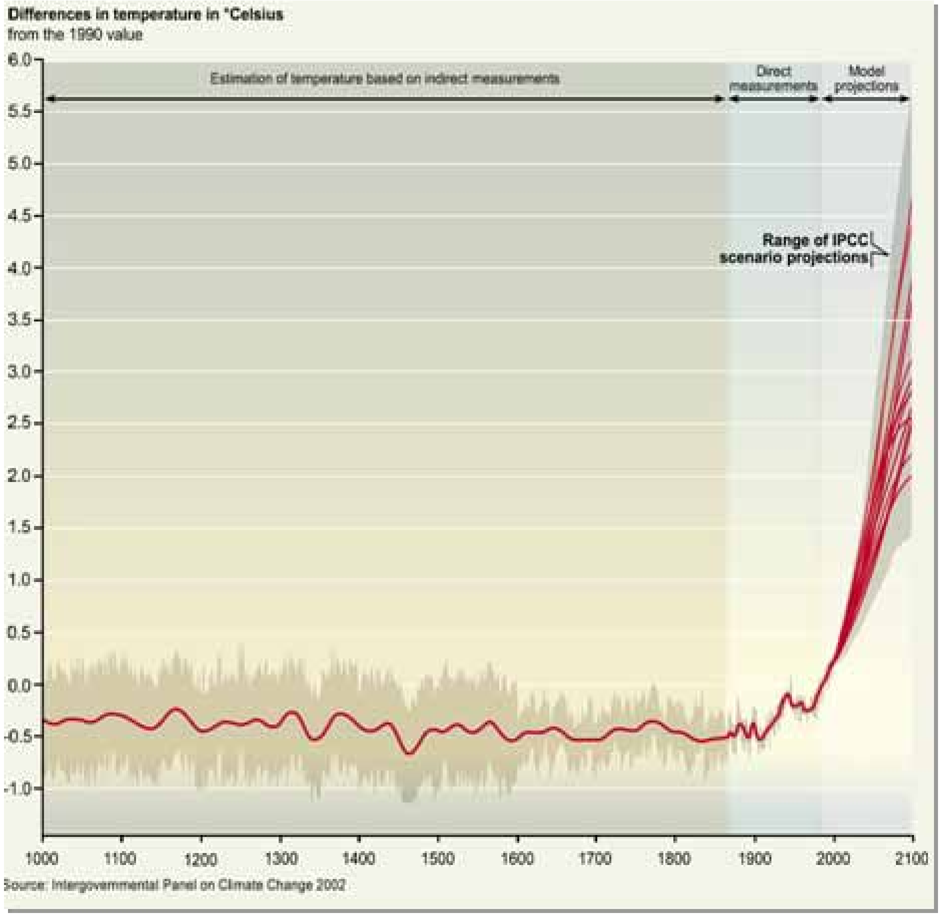
P.K. Aggarwal, P.K. Joshi, J.S.I. Ingram and R.K. Gupta, Adapting food systems of the Indo-Gangetic plains to global environmental change: key information needs to improve policy formulation, Environmental Science & Policy Volume 7, Issue 6, , December 2004, Pages 487-498.

33 rice–wheat long term experiments in the Indo-Gangetic Plains (IGP) of South Asia, non-IGP in India, and China

- extent of yield stagnation or decline
  - yields of rice and wheat stagnated in 72 and 85% of the LTE, respectively, while 22 and 6% of the LTE showed a significant ($P<0.05$) declining trend for rice and wheat yields, respectively.
  - rice yields are declining more rapidly than wheat.
  - causes mostly location-specific:
    - depletion of soil K
    - depletion of soil C, N and Zn and reduced availability of P
    - delays in planting, decreases in solar radiation and increases in minimum temperatures.

      J*. K. Ladha, D. Dawe, H. Pathak, A. T. Padre, R. L. Yadav, Bijay Singh, Yadvinder Singh, Y. Singh, P. Singh, A. L. Kundu, R. Sakal, N. Ram, A. P. Regmi, S. K. Gami, A. L. Bhandari, R. Amin, C. R. Yadav, E. M. Bhattarai, S. Das, H. P. Aggarwal, R. K. Gupta and P. R. Hobbs, How extensive are yield declines in long-term rice-wheat experiments in Asia?, Field Crops Research Volume 81, Issues 2-3, , 20 February 2003, Pages 159-180.*

- Global interactions
  - Food imperative
  - Land quality and availability
  - Climate change and variability
  - Energy / nutrient costs
- Soil condition trends
- Institutional decline
- Fragmentation / history



And – new solutions to the challenge

- ICT opportunities
- DSM breakthroughs
- Sensing – remote, proximal
- Carbon – the new currency
- Awareness – need for a new or renewed ‘green revolution’ (eg. the Alliance for a Green Revolution in Africa: http://www.agra-alliance.org/)

And why are soil scientists important in this?

- The soil is back in centre stage
  - Losses in carbon, nutrients; decline in pH, loss of topsoil, salinisation – have large, uncertain and increasing costs
  - New policies / programs need better scientific input to reduce costs / uncertainties
  - Carbon, nitrogen and methane now part of a global greenhouse account – in reality and soon in policy?
- New opportunities and capabilities
- Need to mobilise and focus

The solution – a global soil information system?

- The right soil information in the right place – integrated into systems answers

- Right information?
  - Understanding of soil processes – modelled
    - Drivers of change in soil processes
      - Land use management
      - Climate change and variability
      - Scope for beneficial and sustainable change
    - The processes which impact people and environment – now and in the future?
  - Measuring / monitoring the processes
    - The key parameters – or
    - Surrogates for the key parameters with known inference capacity
    - Measured / predicted uncertainty

- Right place
  - The parameters needed by the decisions
    - Has to be models of various types
  - The other components / parameters needed for the decisions
  - Resolution to match management scale
  - Everywhere management / impact is an issue
  - Measured / predicted uncertainty

- Systems
  - To feed into integrated systems responses
    - Across biophysical elements
    - Including social and economic dimensions of the impact and the solutions
  - About partnerships, communication and shared progress

The underpinnings

- A soil information system in a grid
- Rapid quantitative measurement
- Integrated systems models

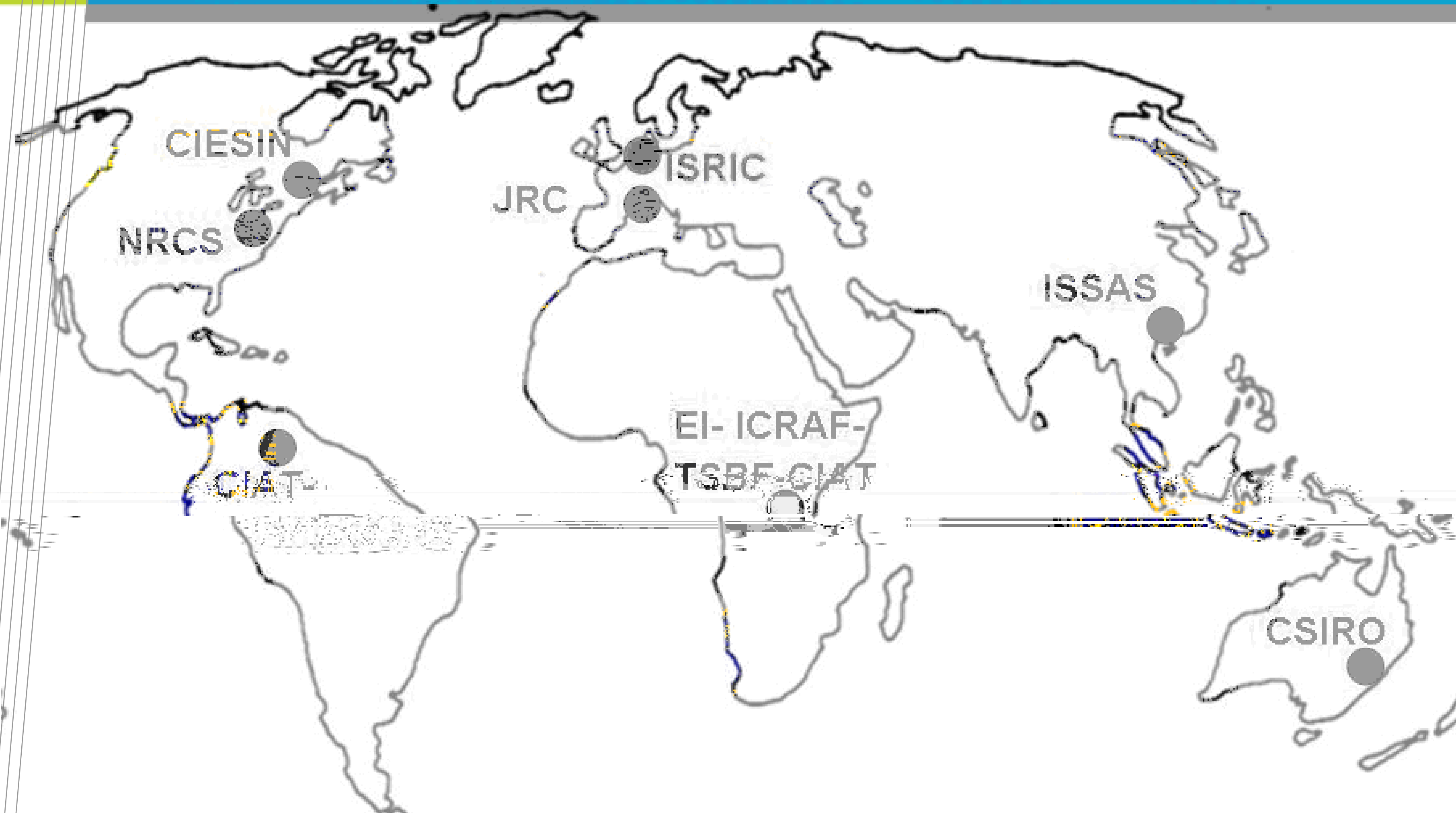
Global digital map of the world

- Aim: an information key to soils drivers to:
  - enhanced food production and poverty reduction,
  - soil erosion reduction and
  - greenhouse gas management.

http://www.globalsoilmap.net/.

Vision

- *Grid at 90 x 90m*
- *Content: primary functional properties of soils*
- *Timing and extent: 80 percent of the world within 5 years*
  - *freely available, web-accessible and widely distributed*
- *an aid to decisions in real time deriving specific management recommendations on enhanced food production, reduced erosion, reduced greenhouse gas emissions and regenerated degraded lands*


CIESIN
NRCS
JRC
ISRIC
ISSAS
CIAT-
EI- ICRAF-
TSBF-CIAT
CSIRO

To produce:

- The key components allowing forecasts on threats to soil function and opportunities for improvement – online
- robust understanding of the key functional components and responsiveness of the world’s soils
- new methods for digital soil mapping and online delivery
- quantification of soil organic carbon and nutrient dynamics to meet the emerging greenhouse requirements
- influence into national policies, programs and assessments especially around food production, avoidance and/or alleviation of land degradation and the interaction with climate policies and targets

Getting there

The end point

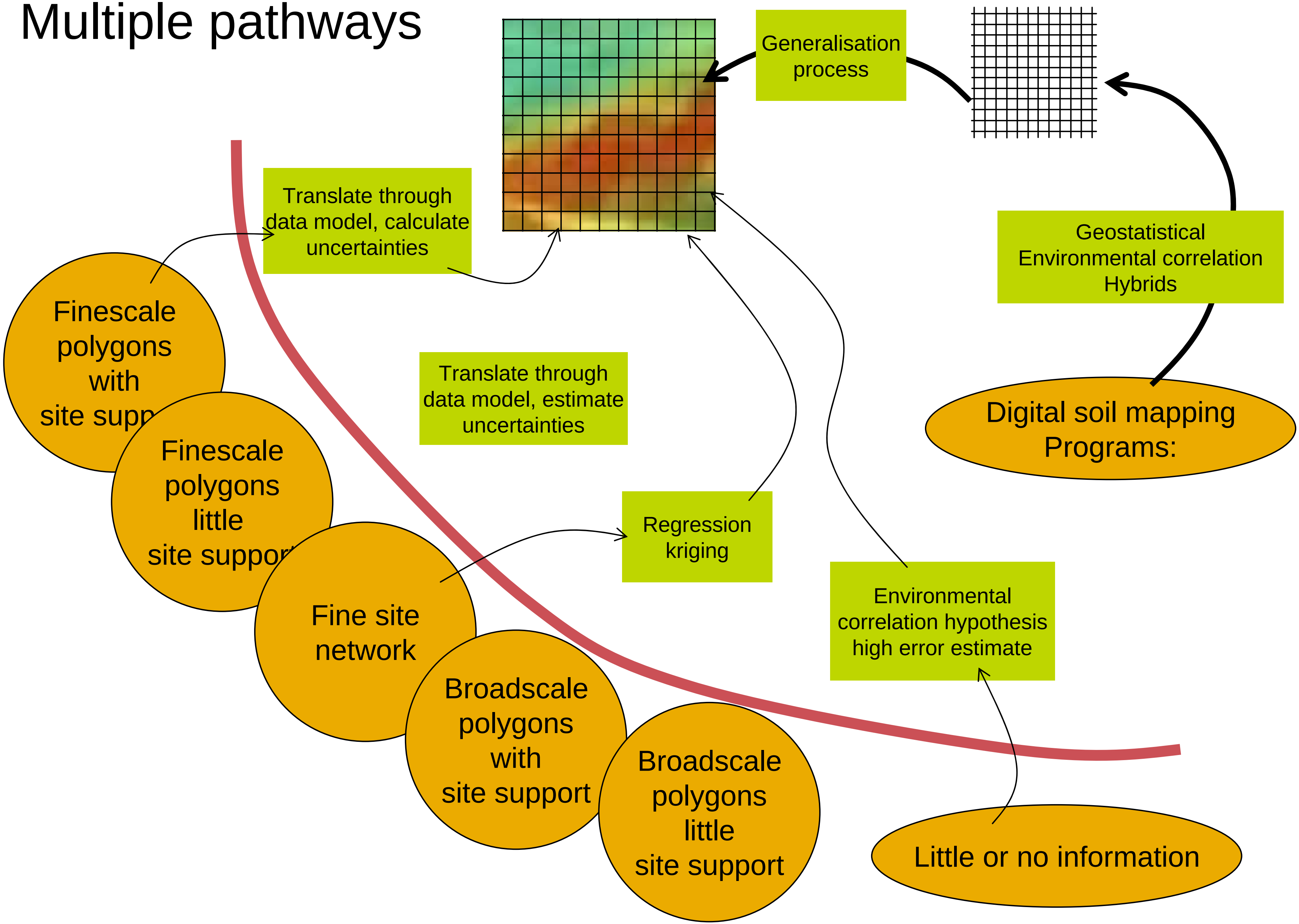
- Information to address these kind of interactions:
  - Economics, ecology and social health
  - Food production – energy – degradation
  - Climate change – mitigation – sequestration – productivity
  - . . .
  - Spatial and temporal interactions – a common thread
  - ie. some form of modelling
- Data and models which give:
  - capacity to explore options
  - predict the outcomes of evolving or new land management systems across crop and land management systems,
  - capacity to monitor of progress and condition and trend of the soil resource

The data need

- Data to match the scale of measurement, the scale of the relevant process, the scale of landscape / land system management
- For each grid component:
  - An estimate of the key parameter
  - An uncertainty value
- The key parameters might include:

Attribute	Significance
Texture	Affects most chemical and physical properties. Indicates some processes of soil formation
Clay content	As for texture
Coarse fragments	Affects water storage and nutrient supply
Bulk density	Suitability for root growth. Guide to permeability. Necessary for converting gravimetric estimates to volumetric
pH	Controls nutrient availability and many chemical reactions. Indicates degree of weathering
Organic carbon	Guide to nutrient levels. Indicator of soil physical fertility
Depths of A, B, C horizons or layers, thickness of solum and regolith	Used to calculate volumes of water and nutrients, e.g. plant available water capacity, storage capacity for nutrients and contaminants
$\theta_{-10\,kPa}$	Used to calculate water availability to plants and water movement
$\theta_{-1.5\,MPa}$	Used to calculate water availability to plants and water movement
Plant available water capacity	Primary control on biological productivity and soil hydrology
Ksat	Indicates likelihood of surface runoff and erosion. Indicator of the potential for water logging. Measure of drainage
Electrical conductivity	Presence of potentially harmful salt. Indicates the degree of leaching
Aggregate stability	Guide to soil physical fertility. Potential for clay dispersion and adverse impacts on water quality
Sum of exchangeable bases	Guide to nutrient levels. Indicates the degree of weathering
CEC	Guide to nutrient levels. Indicates the degree of weathering. Guide to clay mineralogy (when used with clay content)
ESP	Indicator of dispersive clays and poor soil physical properties
ASC (Great Group)	Shorthand for communication across Australia
WRB	Shorthand for communication internationally
Substrate type	Control on soil formation, landscape hydrology, groundwater movement, nutrients and solutes
Substrate permeability	Affects landscape hydrology and groundwater movement

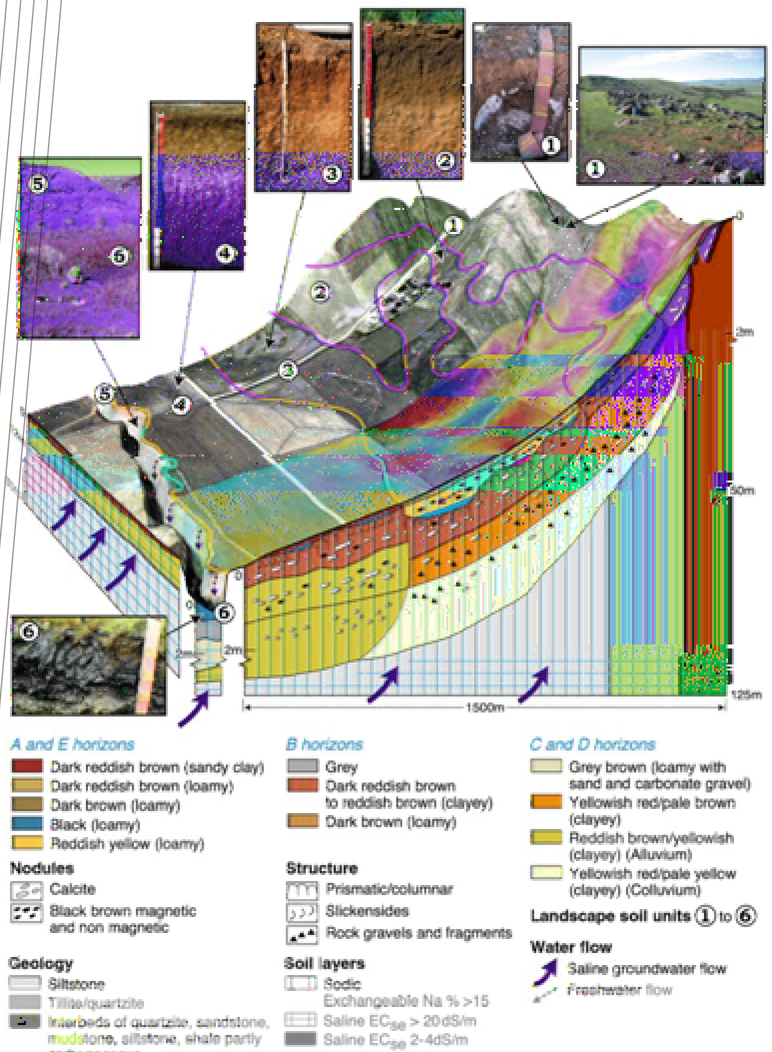
Multiple pathways



Multiple pathways

- For most landscapes and for some time – historic soil survey data will feed the grid
  - Process will be survey and site specific
- The end members:
  - Little effective information – transfer by analogy, expert opinion, correlation with terrain / climate / geological information
  - New survey using digital soil mapping approaches
- Requiring:
  - A fresh approach to a data model
  - Emphasis on pedo-transfer / inference techniques
  - (where possible) supplemental, strategic sampling and measurement
  - Use of remote and proximal sensing, terrain data . . .

Developing a data model – starting from soil survey concepts



- conceptual models of soil–landscape relationships
  - Captured in a formularised way
- Descriptive soil sites
- Analytical sites
- Polygon map
- Map legend
- Survey reports
- And important assumptions:
  - Co-incident attributes between class and polygon
  - Co-variance of important attributes

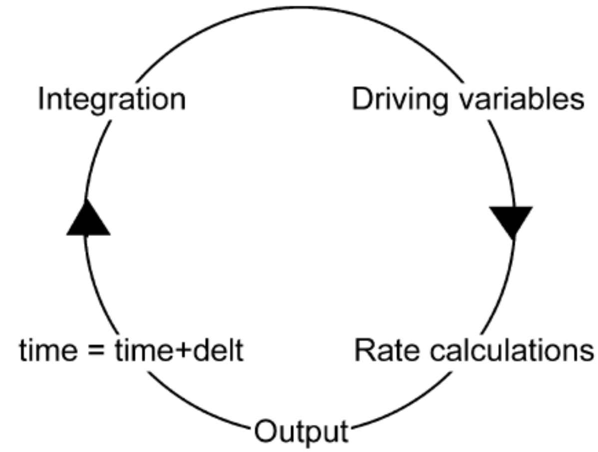
Through model / system concepts

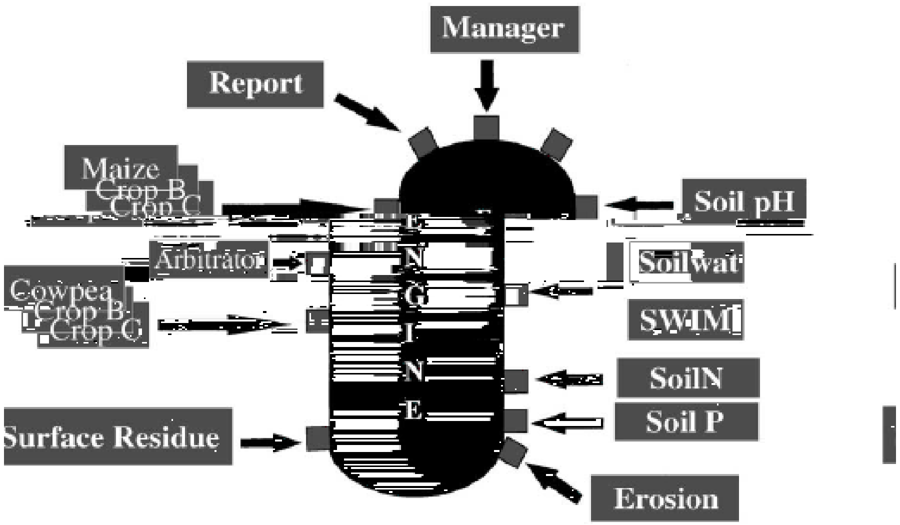
Include:

- point-based one-dimensional models for water balances, forest growth and cropping systems (e.g. APSIM – http://www.apsim.info/apsim/what-is-apsim.asp)
- distributed sediment and water quality models eg. E2 model (Argent et al. 2005) and SEDNET (Prosser et al. 2001).

The soil data:

- complex parameters for water storage, nutrient dynamics, soil erosion, sediment transport and the connections between soils, hillslopes and surface or groundwater.

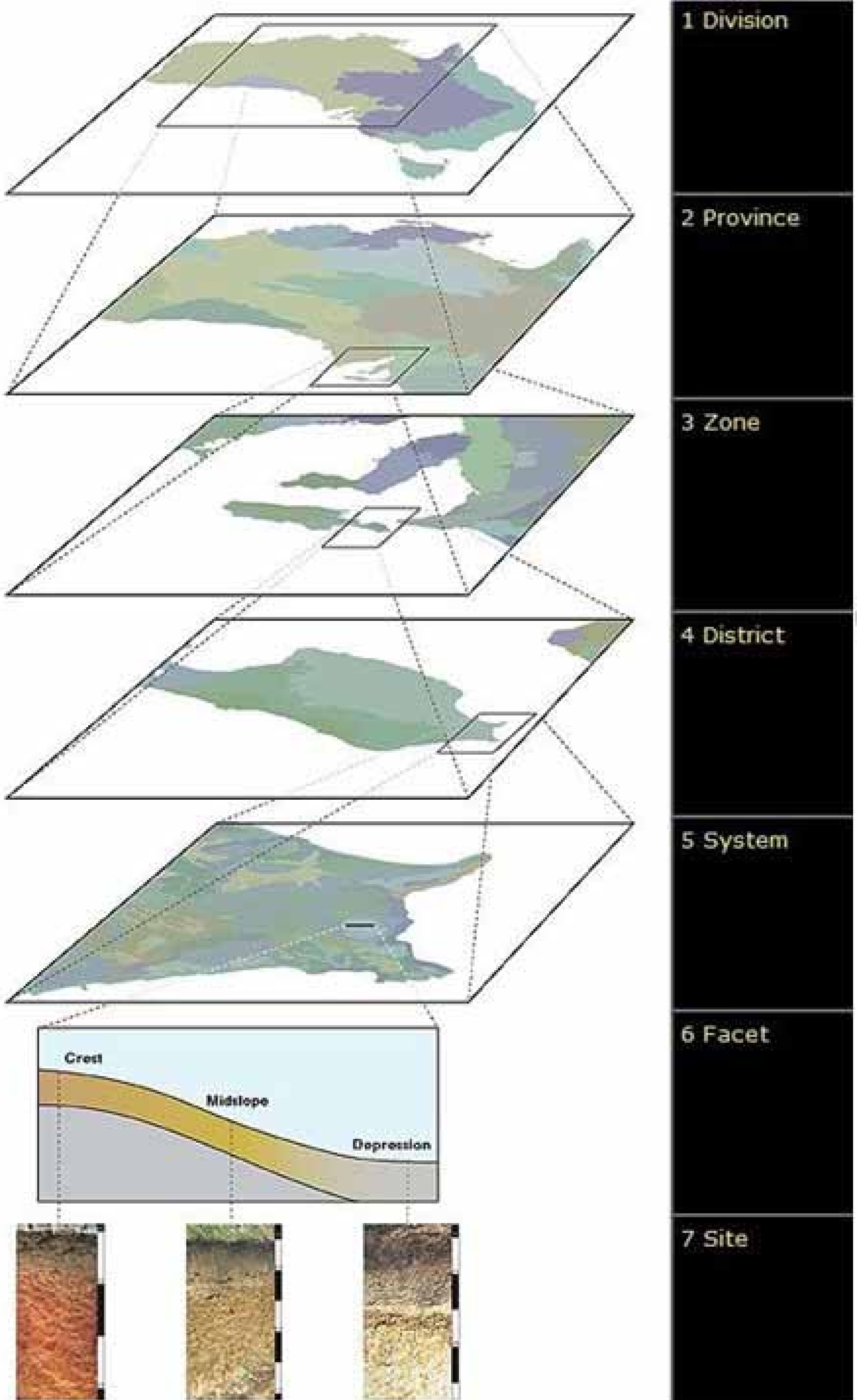




To a data model which:

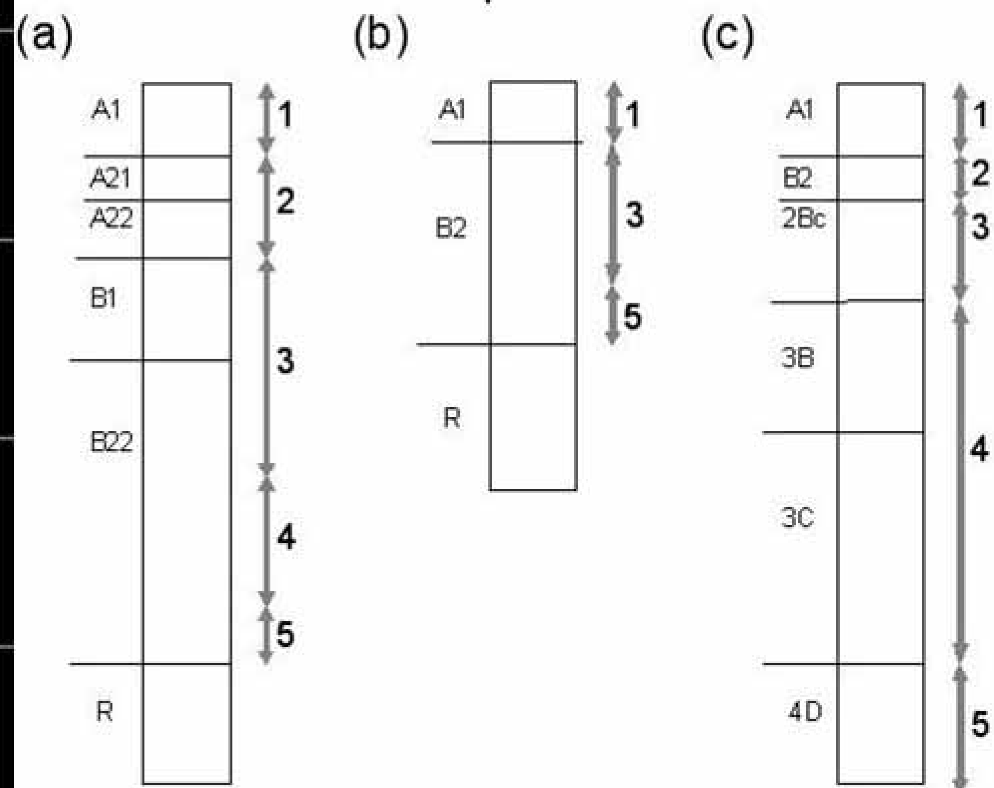
- Fits the population of soils
- Generalises in parameters, depths / layers, volumes – to allow comparison across soils, space and time
- Builds from historic data (vector, traditional data types and structures)
- Fits with a digital, raster expression of soil data
- Allows growth and change

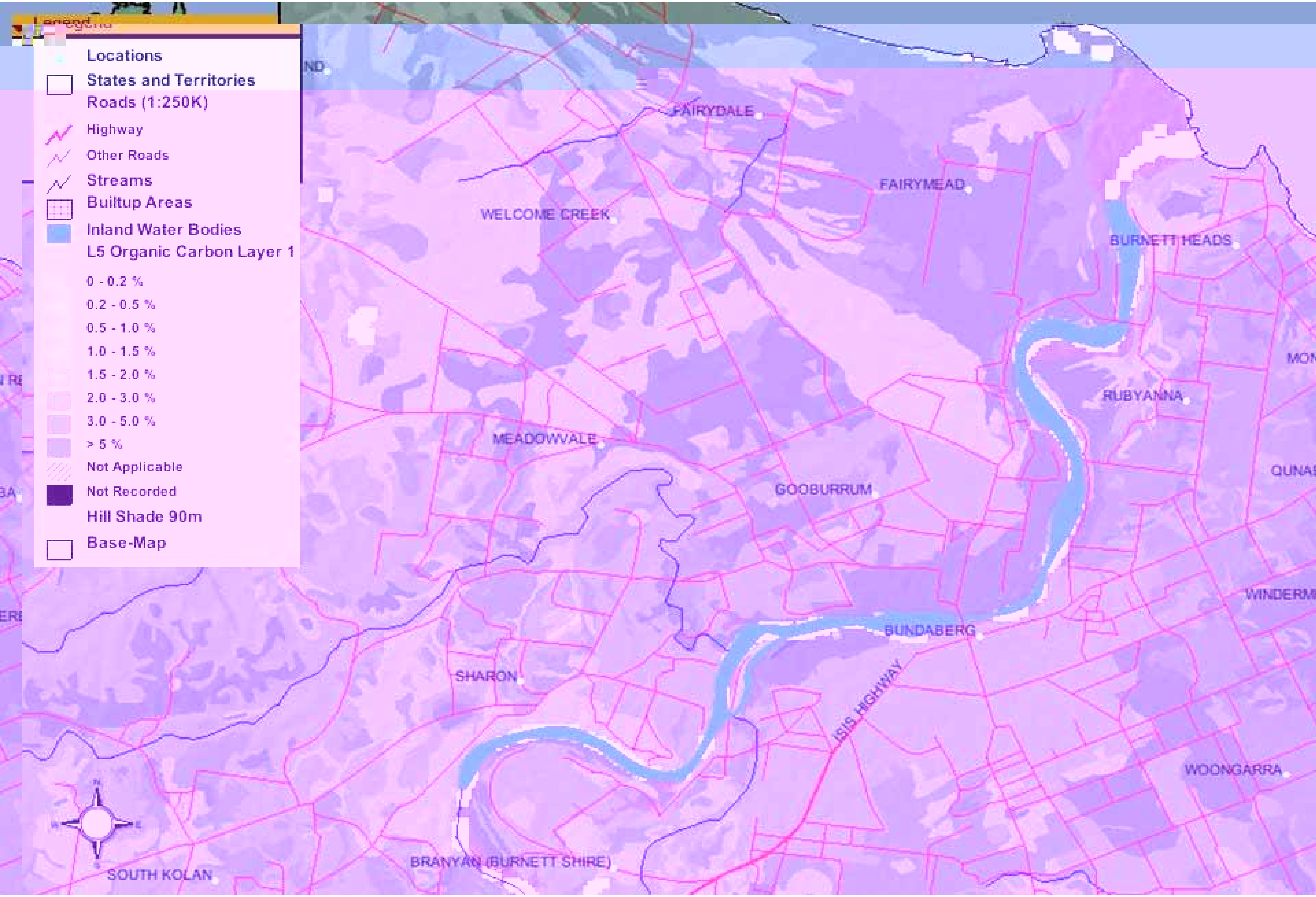
An Australian example: www.asris.csiro.au



ASRIS levels

ASRIS soil layers

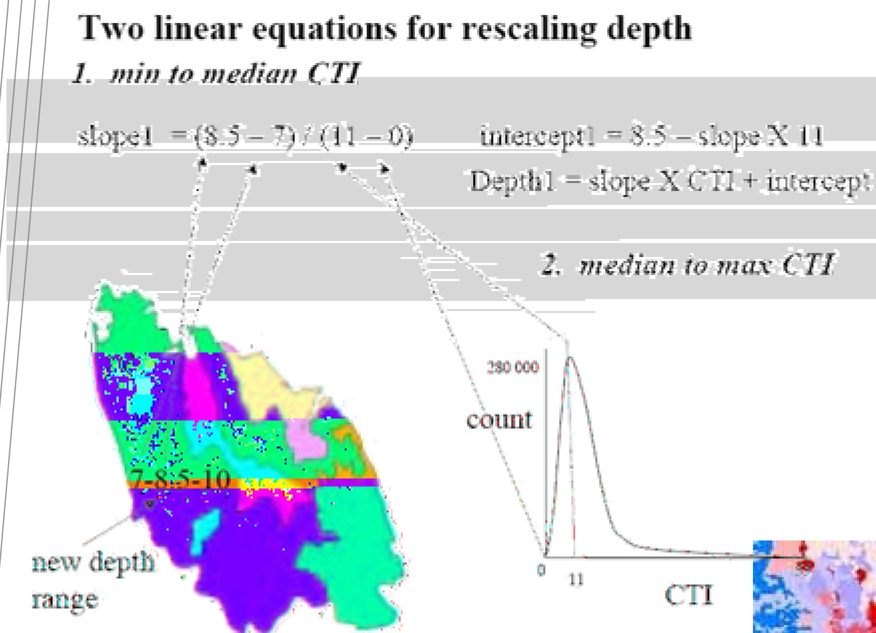


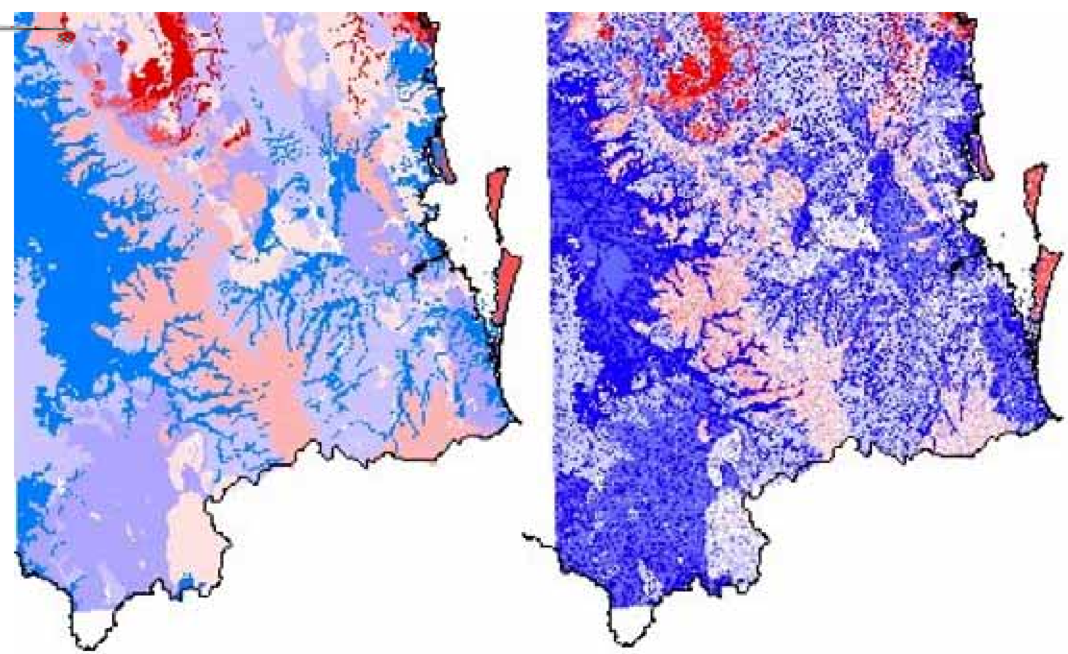


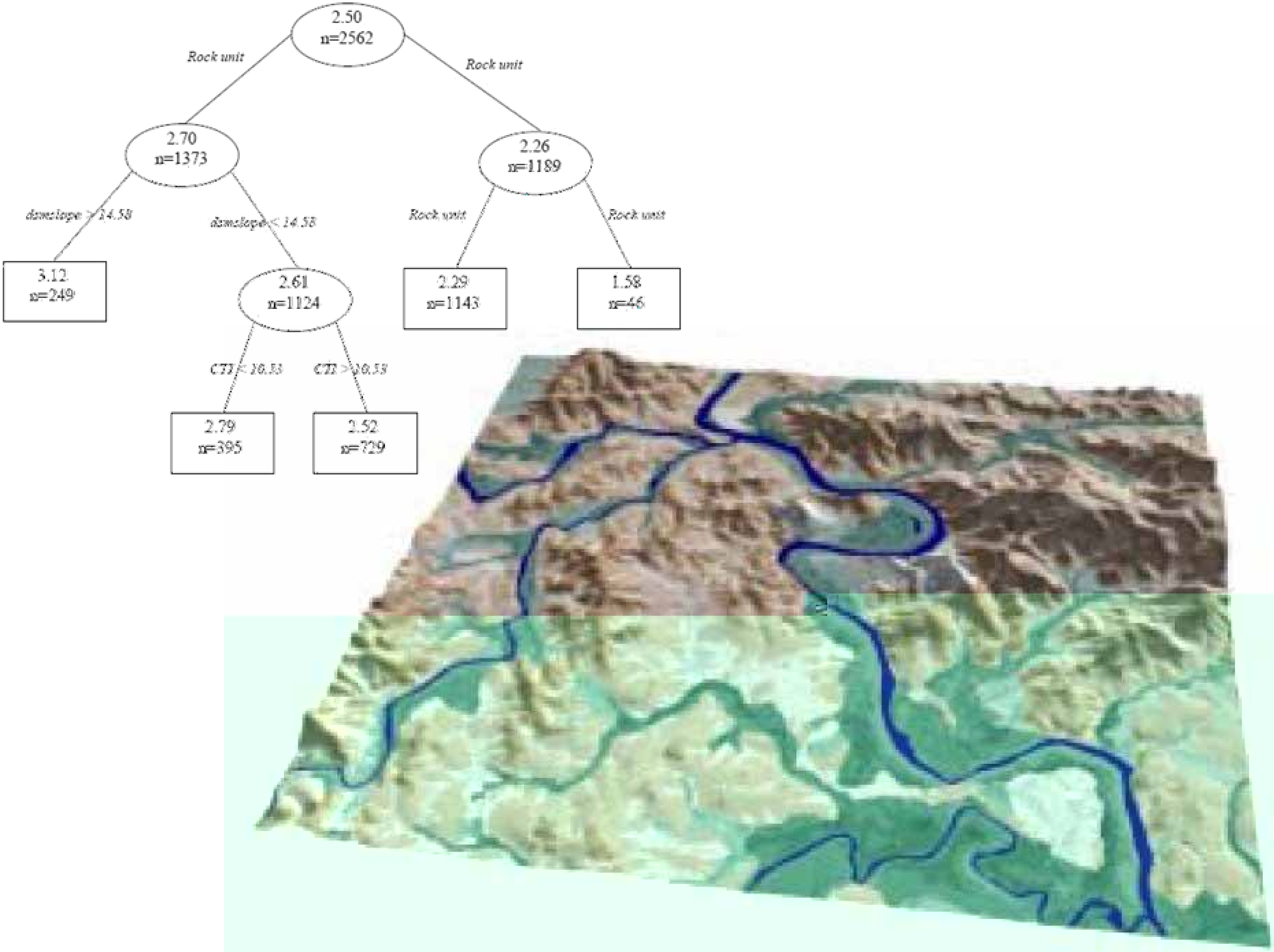
Legend
Locations
States and Territories
Roads (1:250K)
Highway
Other Roads
Streams
Builtup Areas
Inland Water Bodies
L5 Organic Carbon Layer 1
0 - 0.2 %
0.2 - 0.5 %
0.5 - 1.0 %
1.0 - 1.5 %
1.5 - 2.0 %
2.0 - 3.0 %
3.0 - 5.0 %
> 5 %
Not Applicable
Not Recorded
Hill Shade 90m
Base-Map
FAIRYDALE
FAIRYMEAD
WELCOME CREEK
BURNETT HEADS
RUBYANNA
MEADOWVALE
GOOBURRUM
BUNDABERG
SHARON
ISIS HIGHWAY
WOONGARRA
BRANYAN (BURNETT SHIRE)
SOUTH KOLAN
N
E
W
S

Transforming / supplementing historic data

Soil depth – a case of ancillary data with an explicit conceptual model



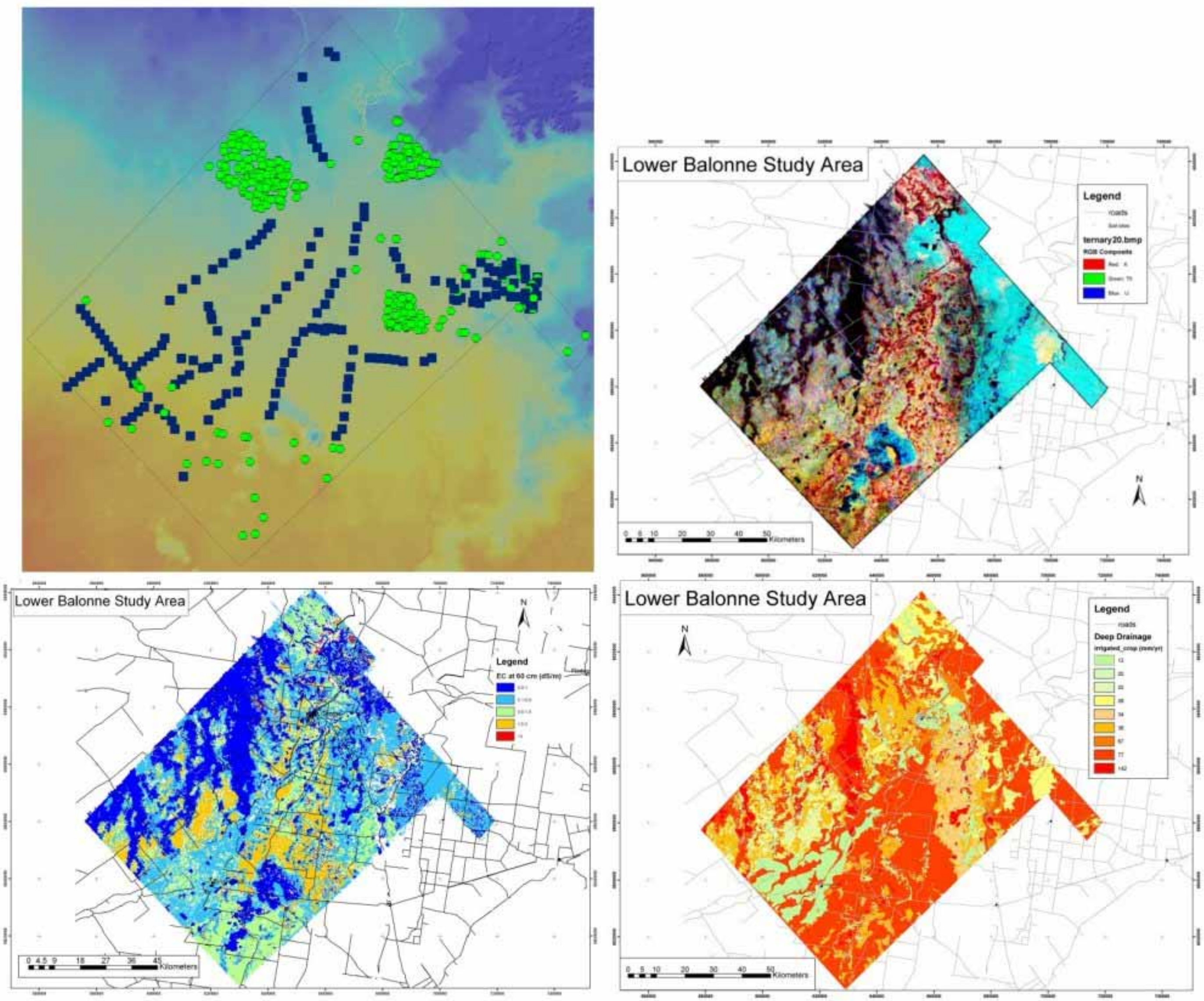



2.50
n=2562
Rock unit
Rock unit
2.70
n=1373
2.26
n=1189
demslope > 14.58
demslope < 14.58
Rock unit
Rock unit
3.12
n=249
2.61
n=1124
2.29
n=1143
1.58
n=46
CTI < 10.53
CTI > 10.53
2.79
n=395
2.52
n=729

A case study: soil modelling for salinity management

- The models – groundwater / surface water interactions; crop performance
- The attributes – soil EC, soil profile drainage, soil texture
- Inadequate soil survey mapping and sites:
  - Supplementary site collection for spatial model building
  - Validation data set collection
- Spatial data modelling – recursive tree approaches based on soil landscape concepts (SCORPAN). Key components:
  - Gamma radiometrics – lithology / parent material
  - DEM – relief

Strategic improvement in soil survey data



Variable	Reported accuracies initial models (Section 3)	Validation accuracies initial models (Section 3)	Accuracies of final models
Drainage	45	33	42
Permeability	73	3	
ASC order	54	14	46
A texture	32	31	36
B texture	47	56	54
EC at 60cm	34	41	33

Proximal Soil Sensing

	Radiometric							
Soil property	γ-rays	X-ray	DRS	Microwave / Radar	Acoustic / Radio	EMI	Electro-chemical	Mecha-nical
available water		x	x	x	x	x		
carbon			x					
BD / compaction	x			x	x			x
pH , BC, LR			x				x	
major nutrients N, P, K							x	
minor nutrients e.g. B, Cu, Mn, Zn, Mo ..etc.		x					x	
clay minerals	x	x	x					
elements e.g. Al, Fe, Si, Mg, Ca, K, etc.	x	x					x	
clay, silt, sand	x		x		x	x		
CEC			x					
salinity						x	x	
heavy metals		x	x					

And the new world?

- The components of digital soil mapping:
  - Sampling to support statistical inference eg. latin hypercube designs
  - Prediction and inference
  - Statistical modelling and environmental correlation
  - Attribute inference eg. pedotransfer functions
- A set of approaches which populate the global soil map directly
- The norm by ???

We are on the way

- Melinda and Bill Gates Foundation involvement
- Initial work in US, Europe and Oceania
- Governance / organisation structure evolving
- Next steps in Utah, Sept/Oct

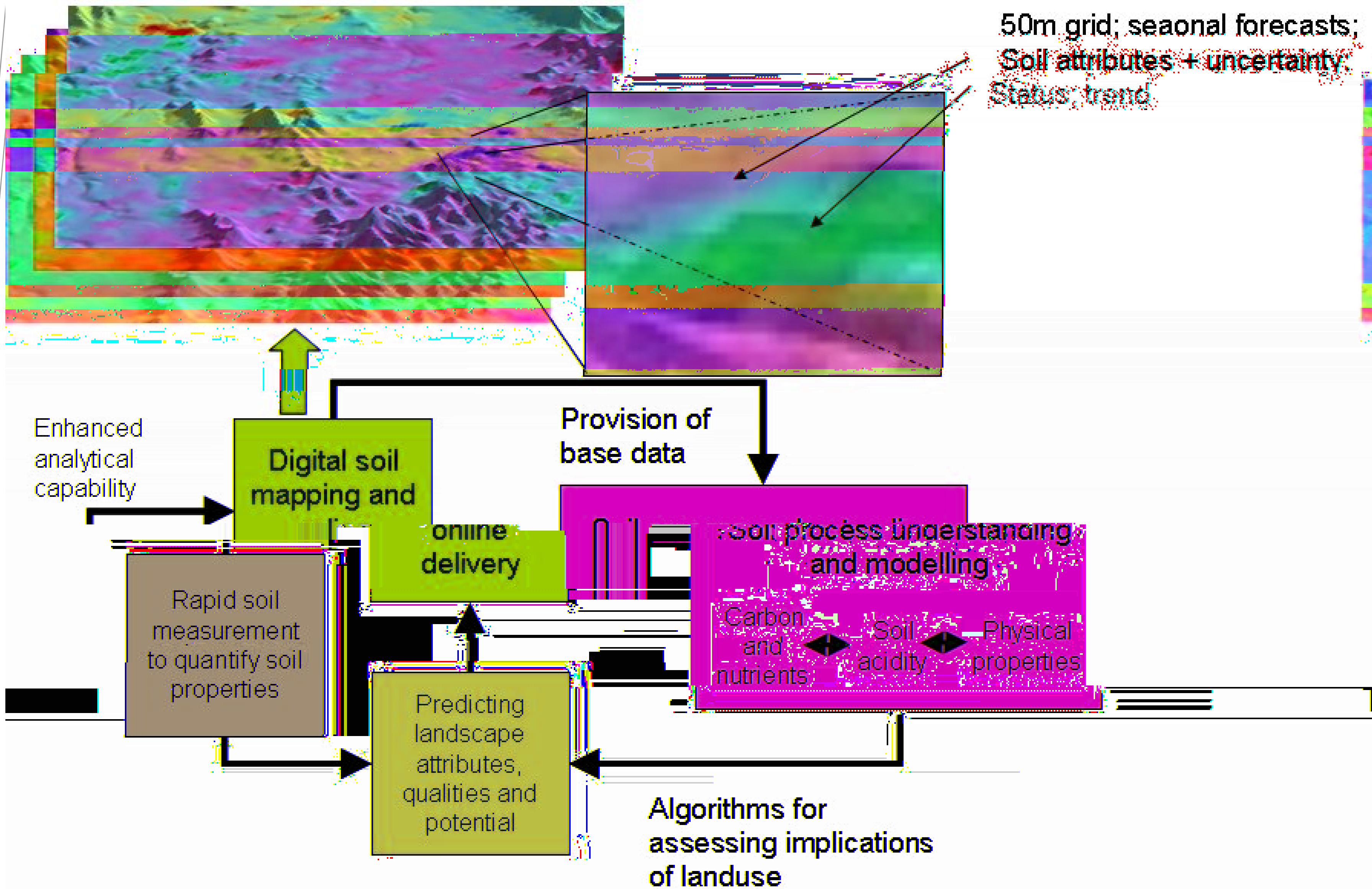
And to finish – some Australian news:

The Australian soil research / survey structure

- States have land management responsibilities and the (declining) soil survey programs, some variable soil research capacity
- CSIRO – national research facility; reinvesting after a decline in investment
  - Provides research support to survey and related programs and to Fed programs
  - Underpins the national soil information system
- University research – small, in clusters, declining in many areas
- Australian Collaborative Land Evaluation Program led by CSIRO includes main players and guides the development of standards, new approaches through National Coordinating Committee on Soil and Terrain

- Australian focus
  - A need to rebuild after disinvestment and fragmentation
  - And to respond to the new needs and opportunities
- CSIRO response – the Theme called “Managing Australia’s Soil and Landscape Assets – MASaLA”

The MASaLA connections



The Goal

To improve the management of Australia's soils and landscapes by

- providing decision makers with definitive seasonal forecasts of key processes (primarily the dynamics of soil carbon, water, nutrients and sediment) affecting or threatening the function of Australian soils
- at a minimum resolution of 50 m across the nation by 2015.

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Thank you

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